U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-270 709

# Toyota-EPA Emission Laboratory Correlation Study

Environmental Protection Agency, Ann Arbor, Mich

Apr 76

OCAR 76-1
PB 270 709

# Toyota-EPA Emission Laboratory Correlation Study

April 1976

Environmental Protection Agency
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Standards Development and Support Branch
Ann Arbor, Michigan

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

| BIBLIOGRAPHIC DATA SHEET | 1. Report No. | 2. | 3. Recipient's Accession No. |
|---|---|---|---|
| 4. Title and Subtitle: Toyota-EPA Emission Laboratory Correlation Study | | | 5. Report Date: April 1976 |
| 7. Author(s): Standards Development and Support Branch | | | 8. Performing Organization Rept. No. CORR 76-1 |
| 9. Performing Organization Name and Address: Standards Development and Support Branch, Emission Control Technology Division, U.S. Environmental Protection Agency, Ann Arbor, Michigan 48105 | | | 10. Project/Task/Work Unit No. |
| | | | 11. Contract/Grant No. |
| 12. Sponsoring Organization Name and Address: SAME as box #9 | | | 13. Type of Report & Period Covered: Technical Support Report |
| | | | 14. |

15. Supplementary Notes

16. Abstracts

EPA received a written request from Toyota Motor Sales, U.S.A. Inc. to conduct a specific correlation program. The program involved a series of hot start exhaust emission tests (2 sample bags), EPA Highway Fuel Economy Tests, and gas cross checks of HC, CO, $NO_x$, and $CO_2$ cylinders. The results of hot start exhaust emission tests, highway fuel economy tests, and a gas cross check analysis show acceptable correlation between laboratories.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Motor vehicles
Exhaust gases
Tests
Test facilities
Fuel consumption

17b. Identifiers/Open-Ended Terms

Test procedures
Measurement methods
Correlation study

17c. COSATI Field/Group

| 18. Availability Statement: Release Unlimited | 19. Security Class (This Report): UNCLASSIFIED | 21. No. of Pages: 11 |
|---|---|---|
| | 20. Security Class (This Page): UNCLASSIFIED | 22. Price: PC A02 - A01 |

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 1982-P74

**Abstract**

A laboratory correlation program between the Ann Arbor Toyota Emission Laboratory and the EPA Motor Vehicle Emission Laboratory has been completed. The results of hot start exhaust emission tests, highway fuel economy tests, and a gas cross check analysis show acceptable correlation between laboratories.

## Introduction

EPA received a written request dated February 2, 1976 from Toyota Motor Sales, USA, Inc. to conduct a specific correlation program. Toyota requested an individual correlation program with EPA prior to the JAMA-EPA program due to CO and NOx instrument replacements, and CVS and dynamometer repairs. EPA agreed to run the Toyota correlation program and on February 12-17 a modified version of Toyota's requested program was conducted at the EPA-NVEL.

### 1. Test Program

#### 1.1 Test Sequence

The correlation program involved a series of hot start exhaust emission tests (3 sample bags), EPA Highway Fuel Economy Tests, and gas cross checks of HC, CO, NOx, and $CO_2$ cylinders.

The test sequence at each test site consisted of the following emission and fuel economy tests:

| | |
|---|---|
| Toyota Corolla 2250# IW | 3 Hot-start, 3 bag tests |
| | 2 Highway Fuel Economy Tests |
| Toyota Hi-Lux @ 3000# IW | 3 Hot-start, 3 bag tests |
| | 2 Highway Fuel Economy Tests |

In addition, 1 HC, 6 CO, 1 NOx, and 2 $CO_2$ cylinders were analysed at each laboratory.

### 2. Test Vehicles

The test vehicles used for this program were a 1976 Toyota Corolla, 2250# IW, 1.6 litre, 4 speed manual transmission; and a 1976 Toyota Hi-lux Pickup, 3000# IW, 2.3 litre, 4 speed manual transmission. Each vehicle was tested using leaded indolene fuel. The same test driver drove all tests at Toyota and EPA.

#### 2.1 Preconditioning:

Each test vehicle was used to stabilize the dynamometer and set the indicated absorbed horsepower at 30 mph. This was equivalent to 15 minutes of operation at 30 mph, 5 minutes at 50 mph, and approximately 1 minute at idle. The previous emission or fuel economy test was used for preconditioning for the sequential emission or fuel economy tests.

2.0 Facilities

2.0-1 Equipment: Emission and fuel economy tests were performed using the dynamometer, sampling system, and analytical equipment which is devoted exclusively to all emission testing at the Toyota Ann Arbor Laboratory.

Tests at the EPA-NVEL used dynamometer No. 1, CVS 310, analysis train #9; and dynamometer No. 2, CVS 330, and analysis train #10.

A complete description of the Toyota and EPA equipment used for the correlation program is presented in Table 1.

2.0-2 Calibration: Prior to the tests at Toyota and EPA, dynamometers, CVS's, and analytical systems were determined to be in good operating condition. Checks and calibrations were performed in accordance with current Federal Register requirements.

3. Test Results

3.1 Emission and Fuel Economy Results

Test results are summarized in Table 2 for the Toyota Corolla, and in Table 3 for the Toyota Hi-Lux. Values for $V_{cc}$ (hot transient), and $V_{ss}$ (hot stabilized) have units of grams per phase. Composite values are computed in grams/mile and fuel economy in miles/gal. NOx results are reported as corrected values.

3.2 Gas Cross Checks

Ten gas cylinders of known concentration were analyzed at each laboratory using the same analysis equipment that was used for the emission and fuel economy tests. The results of the gas cross check are presented in Table 4.

The largest difference between measurements was 3.4% for a single CO cylinder. All other comparisons checked within 3 percent of all concentrations.

3.3 Discussion of Test Results

The mean values of the hot start emission results and fuel consumption that were measured by Toyota and EPA are compared by using the independent "t" statistic, and presented in Tables 5 and 6. An examination of the test results shows generally good correlation between laboratories. At the 99% confidence level no statistically significant differences were proven. At the 90 and 95 percent confidence levels differences were observed in measurements

Table 1

TEST SITE INSTRUMENTATION

| Analyzer | EPA #3 & 15 | Toyota |
|---|---|---|
| HC | Beckman 400<br>0-50, 100 ppmC<br>$H_2/N_2$ fuel | Horiba FIA 21<br>0-100, 300 ppmC<br>$H_2/N_2$ fuel |
| CO | Bendix 8501<br>0-350, 500 | Horiba AIA 21-A8<br>0-100, 300 |
| NDO | NDA 202<br>0-1000 | Horiba AIA 21-A8<br>0-1000 |
| $CO_2$ | NDA 202<br>0-2.5% | Horiba AIA-21<br>0-2.0% |
| NOx | TECO 10<br>0-100, 250 | Horiba CLA-21<br>0-50, 200, 500 |
| Analyzer Bench | Homebuilt | Horiba MEXA-1300 |
| CVS | Aerocontronic Ford CFV | Horiba PDP |
| Dynamometer | Clayton CTR-30<br>Flywheel Driven<br>Inertia Simulation | Clayton CTR-30<br>Flywheel Driven<br>Inertia Simulation |
| Driver's Aid | Varian, 8" FS = 60 mph<br>4"/min. Preprinted trace | Varian, 8" FS = 60 mph<br>4"/min. Preprinted trace |
| Computer | IBM 370, Off-line | Fujitsu<br>Facom-230-45S |

Table 2

Toyota Corolla

| Test Site | | | Toyota | | | [illegible] | | |
|---|---|---|---|---|---|---|---|---|
| Date | | 2/11 | 2/11 | 2/11 | 2/12 | 2/12 | 2/12 |
| Throttle Stop. | | | 2250 | | | 2250 | |
| Bar. Pressure in Hg. | | 29.17 | 29.19 | 29.19 | 29.02 | 28.85 | 28.82 |
| Dry Bulb/Wet Bulb °F | | 77.5/55.7 | 76.4/55.4 | 76.6/55.4 | 74.5/56.9 | 75.0/56.5 | 75.5/56.8 |
| Relative Humidity % | | 22 | 22 | 22 | 30 | 28 | 25 |
| Mix Corr. Factor $F_E$ | | 0.837 | 0.836 | 0.836 | 0.832 | 0.844 | 0.832 |
| 2 Bag 1A-4 Bar Start | | | | | | | |
| $V_{ST}$ (gr/phase) | HC | 2.68 | 3.27 | 3.36 | 2.97 | 2.81 | 3.36 |
| | CO | 27.76 | 24.96 | 26.85 | 28.38 | 28.49 | 26.78 |
| | NOx | 7.72 | 8.17 | 8.03 | 8.74 | 8.45 | 8.54 |
| | $CO_2$ | 1126.9 | 1134.2 | 1134.9 | 1138.5 | 1139.7 | 1138.0 |
| $V_S$ (gr/phase) | HC | 2.66 | 3.15 | 3.17 | 3.15 | 2.86 | 3.08 |
| | CO | 41.83 | 38.72 | 40.53 | 41.35 | 42.47 | 40.96 |
| | NOx | 4.38 | 4.70 | 4.62 | 4.86 | 4.74 | 4.82 |
| | $CO_2$ | 1381.9 | 1445.8 | 1437.0 | 1441.2 | 1421.8 | 1440.6 |
| $V_{corr}$ (gr/mi) | HC | 0.71 | 0.86 | 0.87 | 0.82 | 0.77 | 0.89 |
| | CO | 9.17 | 8.45 | 8.88 | 9.37 | 9.48 | 9.03 |
| | NOx | 1.61 | 1.72 | 1.69 | 1.81 | 1.78 | 1.78 |
| | $CO_2$ | 334.5 | 346.8 | 342.8 | 342.4 | 338.9 | 342.8 |
| MPG (avg) | | 37.8 | 37.3 | | 35.3 | 36.8 | |

Table 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Test Site | | | | | | | |
| Date | | 2/11 | 2/11 | 2/11 | 2/13 | 2/13 | 2/17 |
| Sample Num. | | | 3000 | | | 3000 | |
| Ave. Pressure in Bg. | | 29.21 | 29.22 | 29.22 | 29.15 | 29.17 | 28.99 |
| Dry Bulb/Wet Bulb °F | | 77.1/54.0 | 77.5/54.0 | 77.9/54.0 | 74.5/54.0 | 73.5/54.0 | 77.5/45.5 |
| Relative Humidity % | | 18 | 18 | 17 | 23 | 25 | 40 |
| Mix Corr. Factor $F_3$ | | 0.813 | 0.812 | 0.811 | 0.825 | 0.830 | 0.923 |
| 2 Deg 12-4 Act Start | | | | | | | |
| $V_{HC}$ (parts/mm) | HC | 1.94 | 2.51 | 2.61 | 2.17 | 2.56 | 2.34 |
| | CO | * | 25.73 | 23.98 | 28.79 | 25.85 | 31.74 |
| | NOx | 10.09 | 10.26 | 10.15 | 10.08 | 10.15 | 5.04 |
| | $CO_2$ | 1442.2 | 1453.2 | 1438.7 | 1587.4 | 2405.5 | 2424.46 |
| $V_{CO}$ (parts/mm) | HC | 2.37 | 2.64 | 2.62 | 2.36 | 2.37 | 2.33 |
| | CO | * | 35.60 | 35.07 | 35.92 | 35.46 | 35.89 |
| | NOx | 5.10 | 5.18 | 5.08 | 4.79 | 4.86 | 4.79 |
| | $CO_2$ | 1847.2 | 1845.0 | 1831.1 | 1811.2 | 1813.2 | 1868.1 |
| $V_{NOx}$ (parts) | HC | 0.60 | 0.69 | 0.70 | 0.66 | 0.66 | 0.62 |
| | CO | * | 9.18 | 7.82 | 8.63 | 8.17 | 5.02 |
| | NOx | 2.05 | 2.06 | 2.03 | 1.98 | 2.09 | 1.84 |
| | $CO_2$ | 438.6 | 439.9 | 435.9 | 429.2 | 429.7 | 441.7 |
| Miss (avg) | | 29.1 | 29.4 | | 29.3 | 30.1 | |

* Toyota CO result deleted, possible incorrect span setting.
** Test Runway Twice as site #3.

Table 4

GAS ANALYSIS

| Cylinder | Concentration (ppb) | | | $\frac{T-E}{E} \times 100\%$ |
|---|---|---|---|---|
| | Nominal | EPA | Toyota | |
| $C_3H_8$ | 78.50 | 80.4 | 78.5 | -2.3 |
| CO | 49.8 | 51.2 | 48.8 | -2.7 |
| | 101.0 | 97.7 | [illegible] | +1.8 |
| | 290.0 | 277.5 | 270.0 | +0.2 |
| | 983.0 | 936.9 | 969.0 | +3.4 |
| | 1550.0 | 1543.4 | 1550.0 | +0.5 |
| | 3720.0 | 3730.9 | 3730.0 | -0.03 |
| NOx | 87.9 | 93.3 | 90.2 | -2.6 |
| $CO_2$ % | 1.76 | 1.73 | 1.74 | +1.2 |
| | 3.02 | 3.07 | 3.02 | -1.7 |

Table 5

Toyota Corolla

| | | HC | CO | NOx | $CO_2$ | FET |
|---|---|---|---|---|---|---|
| Toyota | 1 | 0.71 | 9.17 | 1.61 | 334.3 | 37.0 |
| | 2 | 0.86 | 8.63 | 1.72 | 344.9 | 37.3 |
| | 3 | 0.87 | 8.88 | 1.69 | 343.8 | |
| | $\bar{x}$ | 0.813 | 8.893 | 1.674 | 340.4 | 37.15 |
| | $\sigma$ | 0.090 | 0.270 | 0.057 | 5.2 | 0.21 |
| | c.v. | 11.0 | 3.0 | 3.4 | 1.5 | 0.6 |
| | | HC | CO | NOx | $CO_2$ | FET |
| EIA | 1 | 0.82 | 9.27 | 1.81 | 341.4 | 35.3 |
| | 2 | 0.77 | 9.49 | 1.78 | 338.9 | 36.8 |
| | 3 | 0.89 | 9.03 | 1.78 | 343.0 | |
| | $\bar{x}$ | 0.827 | 9.263 | 1.790 | 341.0 | 36.05 |
| | $\sigma$ | 0.060 | 0.230 | 0.017 | 2.0 | 1.06 |
| | c.v. | 7.3 | 2.5 | 1.0 | 0.3 | 3.9 |
| $\frac{(\bar{x}_T - \bar{x}_E)}{\bar{x}_E} \times 100\%$ | | -1.7 | -4.0 | -6.5 | -0.3 | +3.0 |
| t-statistic | | -0.21 | -1.80 | -3.40 | -0.19 | |
| t-value | | | | | | |
| 99% C.L. 4.60 | | ND* | ND | ND | ND | |
| 95% C.L. 2.78 | | ND | ND | D** | ND | |
| 90% C.L. 2.13 | | ND | ND | D | ND | |

*No Difference exists
**Difference exists

Table 6

Toyota Minivan

| | | HC | CO | NOx | $CO_2$ | FRT |
|---|---|---|---|---|---|---|
| Toyota | 1 | 0.60 | | 2.05 | 438.4 | 29.1 |
| | 2 | 0.69 | 8.18 | 2.06 | 439.9 | 29.4 |
| | 3 | 0.70 | 7.82 | 2.03 | 430.9 | |
| | $\bar{x}$ | 0.661 | 8.00 | 2.047 | 436.47 | 29.25 |
| | $\sigma$ | 0.055 | 0.255 | 0.015 | 4.86 | 0.21 |
| | c.v. | 8.3 | 3.2 | 3.1 | 1.1 | 0.7 |
| | | HC | CO | NOx | $CO_2$ | FRT |
| EPA | 1 | 0.60 | 8.63 | 1.98 | 429.2 | 29.9 |
| | 2 | 0.66 | 8.17 | 2.00 | 428.7 | 30.1 |
| | 3 | 0.62 | 9.03 | 1.84 | 441.7 | |
| | $\bar{x}$ | 0.627 | 8.607 | 1.940 | 433.53 | 30.00 |
| | $\sigma$ | 0.031 | 0.425 | 0.087 | 7.08 | 0.14 |
| | c.v. | 4.9 | 4.9 | 4.5 | 1.6 | 0.5 |
| $\frac{(\bar{x}_T - \bar{x}_E)}{\bar{x}_E} \times 100\%$ | | +5.7 | -7.1 | +5.5 | +0.7 | -2.5 |
| t-statistic | | +2.96 | -1.76 | +2.09 | +0.59 | |
| t-value | | | | | | |
| 99% C.L. 4.60 | | ND | ND 5.84 | ND | ND | |
| 95% C.L. 2.78 | | D | ND 3.18 | ND | ND | |
| 90% C.L. 2.13 | | D | ND 2.35 | ND | ND | |

of oxides of nitrogen for tests with the Corolla and hydrocarbons for tests with the Hi-Lux. The percent difference between Toyota and EPA is -6.3% (Toyota measuring lower) for the NOx results from the Corolla and +5.7% (Toyota measuring higher) for the hydrocarbon results from the Hi-Lux. No other significant differences were apparent for measurements of HC, CO, NOx, $CO_2$ or calculated fuel economy.

Ambient conditions were not thought to effect the correlation between laboratories. Changes in barometric pressure were slight (a maximum difference of 0.37 in Hg) and relative humidity, although low at both laboratories, remained between 17 and 30 percent for all but one test. The dry bulb temperature remained between 73 and 78°F for all tests.

Emissions and fuel economy test results at both laboratories are very repeatable. Only the hydrocarbon test results from the Hi-Lux have a coefficient of variation over 10%. The emission differences between laboratories are less than 7% for all tests except the Hi-Lux hydrocarbon results. The conditions where statistically significant differences are observed are not thought to be important. This is because the emission levels are low and the absolute differences small; the differences were not repeatable for both vehicles; and the sampling and analysis equipment were checked and determined to be operating satisfactorily during all tests.

4. Conclusions

1) HC, CO, NOx, $CO_2$, and fuel economy results agree closely between Toyota and EPA.

2) The statistically significant differences in emission results are not thought to be important because of the low absolute differences in emission results, the significant differences were not observable on both test vehicles, and calibration and gas cross checks results were satisfactory.

5. Recommendations

1) Improved humidity control at both test facilities is needed. Absolute levels of humidity were very low resulting in NOx correction factors near 0.8.